# Coastal and Semi-Enclosed Seas

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## LONG-TERM GOALS

To develop, test, demonstrate and evaluate nowcast/forecast systems for coastal and semi-enclosed seas. These systems are developed and tested in this 6.2 program and then transitioned into a 6.4 program for final evaluation and testing under near real time operational conditions.

## OBJECTIVES

The objective of this project is to determine the important processes that affect the oceanography of semi-enclosed seas, both deep and shallow, that are of Navy interest. This is accomplished through the use of a combination of numerical models and observations, including the assimilation of data. Which processes are included in the numerical models depends upon their importance to the region of Navy interest being modeled. As an example, tides are more important in shallow than in deep semi-enclosed seas. Once the appropriate model is developed and tested within this program, it is transitioned into the U.S. Navy's 6.4 programs for advanced developmental testing before transition into operations, the ultimate goal of the project.

## APPROACH

Numerical model process and sensitivity studies are conducted to better understand the dynamics and thermodynamics of shallow and deep semi-enclosed seas. This is accomplished by both developing/adapting models to regions of key Navy interest and verifying those models against available observations. In addition to the numerical models, data assimilation techniques are developed to improve the models predictive skill. The thrust of the project this year expanded from studying oceanographic processes in the Yellow Sea (Ms Shelley Reidlinger and Ms Andrea Mask) to studying the oceanography of the South China Sea, Yellow Sea and the Sea of Japan, within the structure of one numerical model (Dr. Dong Shan Ko, Sverdrup Technology Inc.). This model is referred to as the East Asian Seas model.

## WORK COMPLETED

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The Yellow Sea POM model was compared to in situ pressure gauge data as well as remotely sensed data (TOPEX/Poseidon altimetry) for model validation purposes.

The model results with tides were compared to results without tides and validated against temperature profiles in the Yellow Sea.

The model was transitioned into the 6.4 program and is now in the process of transition to the Fleet Numerical Meteorology and Oceanography Center for operational implementation.

A modified version of the Princeton Ocean Model was developed for use in the East Asian Seas modeling task. The modified code no longer stores or calculates values over land.

The model grid for the East Asian Seas has been designed. Bathymetry data, temperature and salinity climatology, atmospheric forcing and MCSST's have all been acquired and interpolated to the model grid. Preliminary testing is underway.

## RESULTS

The Yellow Sea model's (POM) sea surface height (SSH) fields (1993-1995), were compared to a statistical linear response model for SSH derived from TOPEX/Poseidon altimetery data and to in situ data pressure gauge data. In this study, the numerical model showed better agreement with the data than the statistical model (Figure 1). Specifically, these comparisons indicated that the highest response between wind stress and SSH was at the 3- and 10-day periods.

The statistical model and the numerical model were also used to show that northerly and southerly wind bursts in the northern Yellow Sea and Bohai Sea create a large SSH anomaly. This anomaly propagates southward along the Chinese coast creating changes in SSH of 20 cm or greater (Figure 2).

Tides were implemented in the Yellow Sea POM model. The model was able to reproduce those areas of largest tidal amplitudes (Figure 3). The Yellow Sea model with tides showed much stronger vertical mixing. In most cases, these results proved more accurate when compared to the XBT data than the results without tides.

Yellow Sea model tests, with and without winds, showed that the Yellow Sea Warm Current is not a direct product of wind forcing. The Warm Current appears to be driven by external forcing from the Taiwan Current or a combination of the Taiwan Current and the Kuroshio. However, winds do modify and steer the current.

## IMPACT/APPLICATIONS

The impact of this project has been to show the importance of the effects of winds, tides and

boundary forcing on the circulation of the Yellow Sea. This project has also shown that these shallow water models provide a reasonable representation of the oceanography of the Yellow Sea/East China Sea that can be improved, via the assimilation of data, to provide forecast products. This project has also been responsible for the development of a POM code that can be applied to larger regions and remain computationally reasonable by not being required to store values over land points.

## TRANSITIONS

The Yellow Sea model developed in this program was transitioned into the 6.4 SPAWAR Small Scale Oceanography program and is presently undergoing operational implementation by the Fleet Numerical Meteorology and Oceanography Center (FNMOC). This model will be FNMOC's first testing of a remote operation capability (Remote OPS) that can allow them to run operational models at computing centers other than their own. The East Asian Seas model is scheduled for deliver to the 6.4 program and then to operations at FNMOC.

## RELATED PROJECTS

NRL 6.1 YES project. Gregg Jacobs PI. Looks at the interaction of wind and external forcing on the oceanography of the Yellow Sea.

SPAWAR 6.4 Small Scale Oceanography project. Tests coastal ocean models in a real time forecasting scenario before they are delivered into operations.

6.2 NOMP Relocatable Nowcast/forecast Systems project. Created temperature and salinity climatology used by the Yellow Sea/East China Sea model and the East Asian Seas model.

ONR funded Dartmouth University Finite Element Modeling of the Yellow Sea. Dan Lynch PI. This project looks at the application of barotropic and baroclinic finite element models to the circulation in the Yellow Sea.

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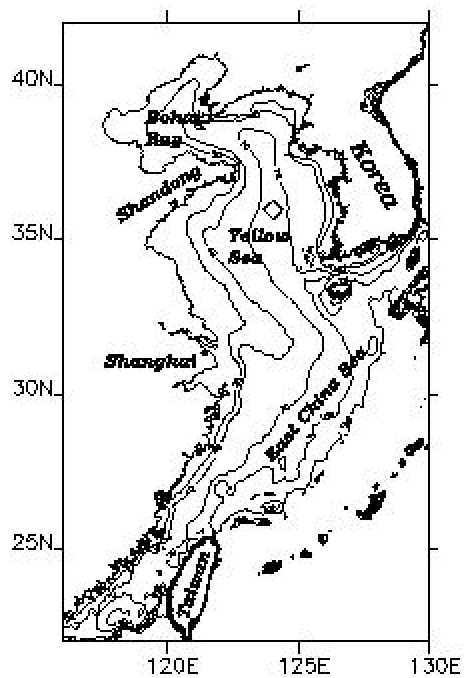
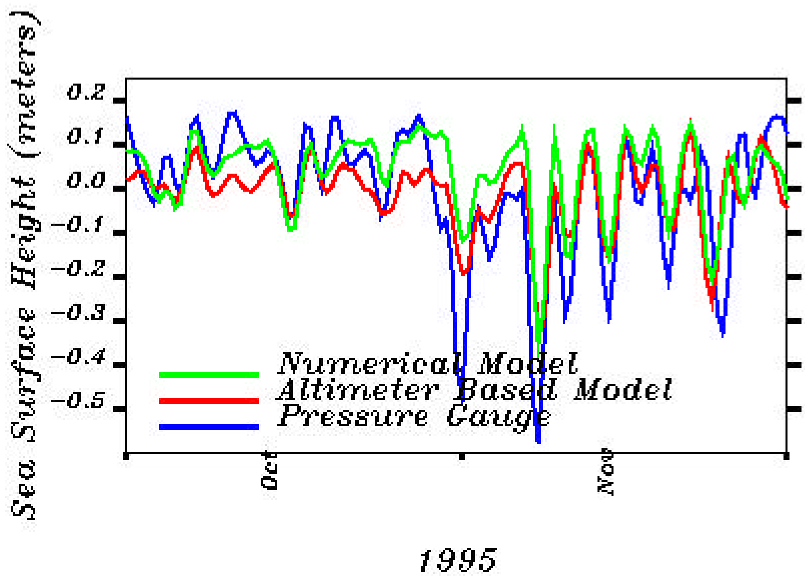
Web address – www7320.nrlssc.navy.mil/html/coastal-home.html

# Figure 1




(a) The contoured bathymetry and the position of the pressure gauge for evaluating the statistical and numerical models.




(b) The SSH time series inferred from the pressure gauge and observed from the statistical and numerical models at the same point..

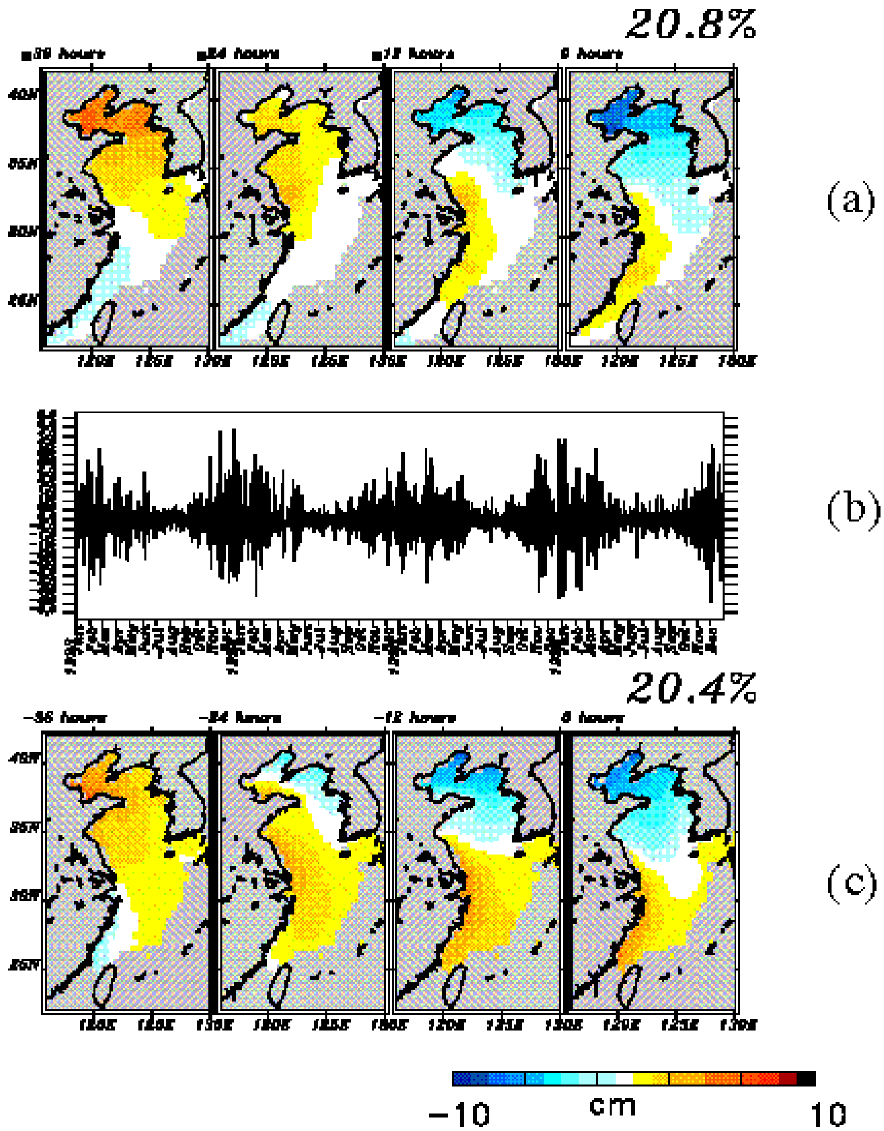



Figure 2. (a) EEOF analysis of a statistical model composed of four years of altimetry data and Navy operational wind fields, (b) the statistical model time series, (c) same EEOF analysis from six months of the model data. The second EEOF mode explains 20% of the variability. Note that as the event develops (left to right) the positive SSH anomaly propagates southward. The time series indicates that these events mainly take place in winter and are associated with strong wind stress events.

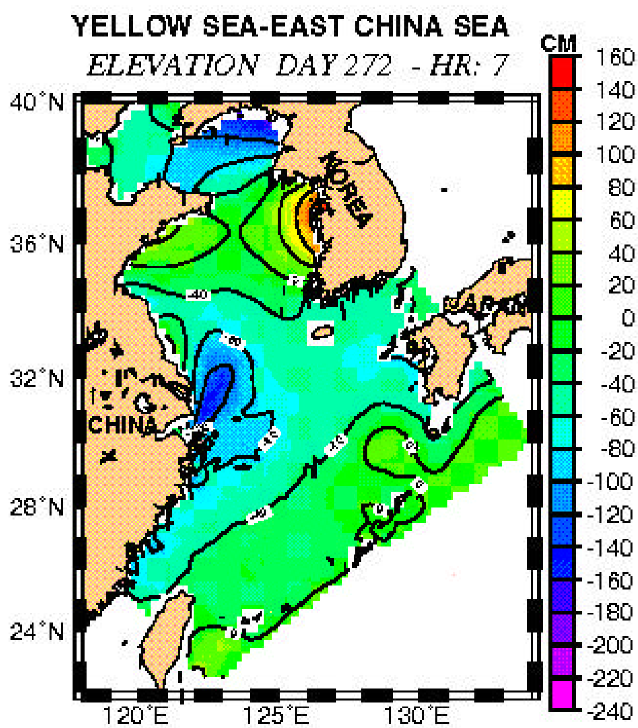



Figure 3. SSH from the Yellow Sea/East China Sea POM model. Note that two regions of strongest tidal amplitude are located along the western coast of Korea near Incheon and along the Chinese coast near the mouth of the Yangzte River.